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(54) IMPROVEMENTS IN OR RELATING TO MOSAIC PRINTER ARRANGEMENTS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company, of Berlin and Munich, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to mosaic printer arrangements.

From German Specification Number 2,144,892, a pulsed droplet ejector device is known comprising a tubular piezoelectric component whose internal diameter changes in response to electrical signals and in so doing ejects printing liquid contained in an ejection passage. This piezoelectric transducer is driven in such a fashion that in its normal, inoperative state it is in an expanded condition. The polarity of the applied voltage is the reverse of the original polarizing voltage applied to the piezoceramic. To eject printing liquid, through the agency of an electronic switch system (in this case a switching transistor) the applied voltage is short-circuited, whereupon the transducer reacts by a sudden contraction and ejects a small droplet of liquid. After the ejection of a droplet, the transducer is again supplied with the original voltage applied to it, and so reverts to its expanded state. This kind of device has the drawback that only a relatively small working stroke can be achieved with the piezo-electric ceramic because if the normally applied control voltage, which is in opposition to the original polarizing voltage, becomes too large there is a risk of depolarizing the ceramic.

If, using this kind of device, several jets are operated, a separate voltage source must be provided for each transducer element. It is an expensive procedure to effect switching of voltages of the order required.

An object of the present invention is to provide a mosaic printer arrangement comprising a piezoelectric drive element, in which it is possible with relatively low drive voltages and optimum efficiency, to achieve a relatively long working stroke. In using several printing jets, the arrangement should be such that short-circuiting of one drive element does not lead to the breakdown of another.

According to the invention, there is provided a mosaic printer arrangement comprising: an ink ejection passage which in use of the arrangement is supplied with ink under pressure, a tubular piezoelectric drive element of polarised ceramic surrounding said passage and provided with electrodes, application to which of a first voltage having one polarity will cause its diameter to increase and application to which of a second voltage having the other polarity will cause its diameter to decrease; and an electrical circuit arranged to supply said first voltage to said electrodes for a determinate period of time and then to supply said second voltage to the electrodes, thereby to cause ejection of ink from said passage.

Said electrodes may be normally supplied with an electrical potential whose sense corresponds to that of said second voltage, in use of the arrangement.

Alternatively, said electrodes may be normally supplied with an electrical potential of zero, in use of the arrangement.

In one embodiment of the invention, the electrical circuit comprises a voltage converter arrangement whose secondary side has an inductance which forms an oscillatory circuit in association with the capacitance of the drive element.

Preferably, the resonant frequency of the oscillatory circuit is identical to that resonant frequency of that liquid column en-

closed by said passage in use of the arrangement, and current pulses supplied in use of the arrangement to the primary side of said converter arrangement each have a duration substantially equal to half the periodicity of said resonant frequency.

The resonant circuit may be damped in respect of pulses of one polarity only by an electrical resistance and a rectifier element connected in series with the resistance.

Said electrical circuit may comprise adjusting means arranged to adjust respective amplitudes of said first and second voltages.

Preferably, said adjusting means is operable to vary the maximum primary current of said voltage converter arrangement.

Where a plurality of ink ejection passages with associated drive elements are provided, each may be supplied from a common voltage source.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the drawings in which:

Figure 1 illustrates a circuit arrangement;

Figure 2 illustrates the form of the drive pulse for the circuit arrangement of Figure 1;

Figure 3 is a graph relating to Figures 1 and 2; and

Figure 4 illustrates how a plurality of circuit arrangements according to Figure 1 may be combined together.

A circuit arrangement is shown in Figure 1, and is driven by pulses produced by a TTL logic circuit 1 whose time-based characteristic has been illustrated in Figure 2. These pulses are matched, *via* a driver stage 2, to the requisite voltage conditions for the circuit arrangement. The driver stage is followed by an amplifier stage consisting of a Darlington transistor 3 which is connected to supply the primary winding of a voltage converter arrangement in the form of a pulse transformer 4. This pulse transformer 4 decouples a piezoceramic tube 5 of a printing jet from the transistor. The inductance of the secondary side of the pulse transformer 4, taken in conjunction with the capacitance of the piezoceramic tube 5, forms an oscillatory circuit which is damped in respect of pulses of one polarity only by a series arrangement of a resistor 6 and a diode 7. The voltage for the overall circuit arrangement is supplied from a common voltage source 8.

Considered in more detail, the circuit arrangement operates in the following way:

The Darlington transistor 3, is driven conductive by a pulse 9 (Figure 2), of width 10, matched by the driver stage 2. Current flows through the collector-emitter path of the transistor 3 and therefore through the primary winding of the pulse transformer 4, inducing in the secondary winding thereof a voltage pulse which excites the oscillatory circuit constituted by the secondary inductance of the pulse transformer 4 and the capacitance of the piezoceramic tube 5. With disconnection of the current at the end 11 of the pulse 9, a voltage is induced in the opposite direction in the primary and secondary of the transformer 4. This occurs at the instant of the first zero transit 13 in the oscillation, so that a pure, only slightly damped sinusoidal oscillation is produced whose amplitude depends upon the change in the primary current and the turns ratio of the transformer 4. As described earlier this oscillation is damped *via* the resistor 6 and the diode 7 in series therewith, so that on the ceramic a voltage characteristic corresponding to that shown in Figure 3 is produced.

The inductance of the secondary winding of the transformer 4 is so matched to the ceramic 5, that the oscillatory circuit has a natural frequency of about 10 kHz corresponding to a periodicity T of around 60 μs. To achieve the optimum voltage characteristic on the ceramic 5, this oscillatory circuit is triggered, in the manner already described, by a primary side current pulse of duration $\frac{T}{2}$ which corresponds to a time of about 30 μs.

The requisite working voltage of the ceramic is adjusted by limting the primary current of the pulse transformer 4. This limiting is achieved *via* the transistor 3 in the Darlington arrangement. In fact, a diode 14 limits the output voltage of the driver stage 2 to a value adjusted by a voltage-divider 15. The control voltage for the transistor 3 can thus be adjusted to between zero and about 8 volts; with application of the control voltage, the transistor 3 is driven conductive. The emitter current in the transistor, however, can only rise until the voltage drop on the emitter resistor 16 and the base-emitter voltage corresponds with the control voltage adjusted on the voltage-divider 15. In this way, the primary current in the pulse 6 transformer 4 can be adjusted to between zero and two Amps, this corresponding to working voltages ranging from zero to about 80 V.

The relatively high voltage drop on the emitter resistor 16 has the effect that the primary current in the pulse transformer 4 is dependent only to a small extent upon the base-emitter voltage of the transistor 3.

Accordingly, the working voltage on the ceramic 5 is maintained adequately constant in the presence of temperature fluctuations.

A Zener diode 17 connected in parallel with the collector-emitter circuit acts, to shunt voltage surges created by disconnection of the primary inductance of the pulse transformer 4, thus protecting transistor 3 against surge voltage damage.

The circuit shown in Figure 1 can be enlarged in a simple fashion to cope with a printer head 18 comprising a plurality of printing jets 5. To this end, as shown in Figure 4, each individual printing jet 5 is assigned a circuit arrangement of this kind and the individual printing jets are driven in a manner known *per se* through a common character generator 19. A common Zener diode 17 is provided for surge protection, whilst the individual collector electrodes are mutually decoupled by respective diodes 20.

All the printing jets can advantageously be supplied from one voltage source 8. Capacitors 21 are provided (although not essential) for the decay of peak voltages. Through the current-limiting taking place at the primary side, in the individual voltage converter arrangements, the result is also achieved that short-circuiting of one jet does not cause the failure of the entire system.

This kind of driving of the drive elements has the major advantage that it is possible to achieve a very large stroke or travel in the ceramic tube, at the expense of relatively small voltage changes. The change in volume of the ceramic tube is at its peak in the neighbourhood of the zero transit on the part of the operating voltage, and consequently the attainable speed of the pressure wave developed in the printing liquid by the volumetric changes, is also at its peak at this point.

Furthermore, depolarizing of the ceramic due to the creation of an over-voltage is virtually excluded because in the inoperative state of the ceramic the latter carries no voltage or, as in a special embodiment, carries a voltage which is codirectional with the polarizing voltage, this also increasing the security of operation of the printer head. The voltage opposing the direction of polarisation is applied only for a relatively short period. In order to produce ink-ejection, the ceramic tube is initially expanded by applying this opposing voltage and then contracted by reversing the voltage. Ink transfer from a reservoir to the actual ejection tube is thus brought about. When the ceramic tube is expanded, this causes ink to be sucked into the ink tube. Surface tension forces acting at the exit orifice of the ink tube at the interface between air and ink, prevent air from entering the printing jet through this opening.

The circuit arrangement produces the requisite voltage characteristic for the driving of the ceramic tubes, in a simple and inexpensive manner. Also, in the event of the system being touched, the output voltage collapses to a non-lethal level owing to the decoupling provided by transformers 4 and in the event of a short-circuit, because of the current-limiting effect at the primary side, the circuit cannot be overloaded. The damping produced by the resistor and the diode, is unilaterally operative and therefore produces an ideal voltage characteristic for operation of the ceramic; the negative voltage rises very slowly until the tube is expanded, whereupon a rapid transition to positive voltage takes place in order to produce ejection, the voltage then decaying slowly until the tube is once again in its normal state. The best efficiency is achieved if the resonance frequency of the oscillatory circuit constituted by the secondary inductance of the transformer 4 and the capacitance of the piezoelectric ceramic, is equivalent to the resonant frequency of the liquid column enclosed in the ink-ejection passage and if the duration of the primary current pulse is equal to half the period of this resonant frequency.

If, several printing jets are combined to form a printer head, then it is possible in an advantageous manner to supply all the printing jets from just one voltage source, i.e. from just one, non-stabilized mains unit. Even so, short-circuiting of a jet does not, owing to the current-limiting action of the primary side, lead to the failure of the entire printer head.

WHAT WE CLAIM IS:—

1. A mosaic printer arrangement comprising: an ink ejection passage which in use of the arrangement is supplied with ink under pressure; a tubular piezoelectric drive element of polarised ceramic surrounding said passage and provided with electrodes, application to which of a first voltage having one polarity will cause its diameter to increase and application to which of a second voltage having the other polarity will cause its diameter to decrease; and an electrical circuit arranged to supply said first voltage to said electrodes for a determinate period of time and then to supply said second voltage to the electrodes, thereby to cause ejection of ink from said passage.

2. An arrangement as claimed in Claim 1 wherein said electrodes are normally supplied with an electrical potential whose sense corresponds to that of said second voltage, in use of the arrangement.

3. An arrangement as claimed in Claim

1 wherein said electrodes are normally supplied with an electrical potential of zero, in use of the arrangement.

4. An arrangement as claimed in any one of Claims 1 to 3 wherein the electrical circuit comprises a voltage converter arrangement whose secondary side has an inductance which forms an oscillatory circuit in association with the capacitance of the drive element.

5. An arrangement as claimed in Claim 4 wherein the resonant frequency of the oscillatory circuit is identical to that resonant frequency of that liquid column enclosed by said passage in use of the arrangement, and current pulses supplied in use of the arrangement to the primary side of said converter arrangement each having a duration substantially equal to half the periodicity of said resonant frequency.

6. An arrangement as claimed in Claim 4 or 5 wherein the oscillatory circuit is damped in respect of pulses of one polarity only by an electrical resistance and a rectifier element connected in series with the resistance.

7. An arrangement as claimed in any one of Claims 1 to 6 wherein said circuit comprises adjusting means arranged to adjust respective amplitudes of said first and second voltages.

8. An arrangement as claimed in Claim 7 when appended to any one of Claims 1 to 5, wherein said adjusting means is operable to vary the maximum primary current of said voltage converter arrangement.

9. An arrangement as claimed in any one of Claims 1 to 8, wherein there is provided a plurality of passages with associated drive elements each supplied from a common voltage source.

10. A mosaic printer arrangement substantially as hereinbefore described with reference to the drawings.

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Fig. 1

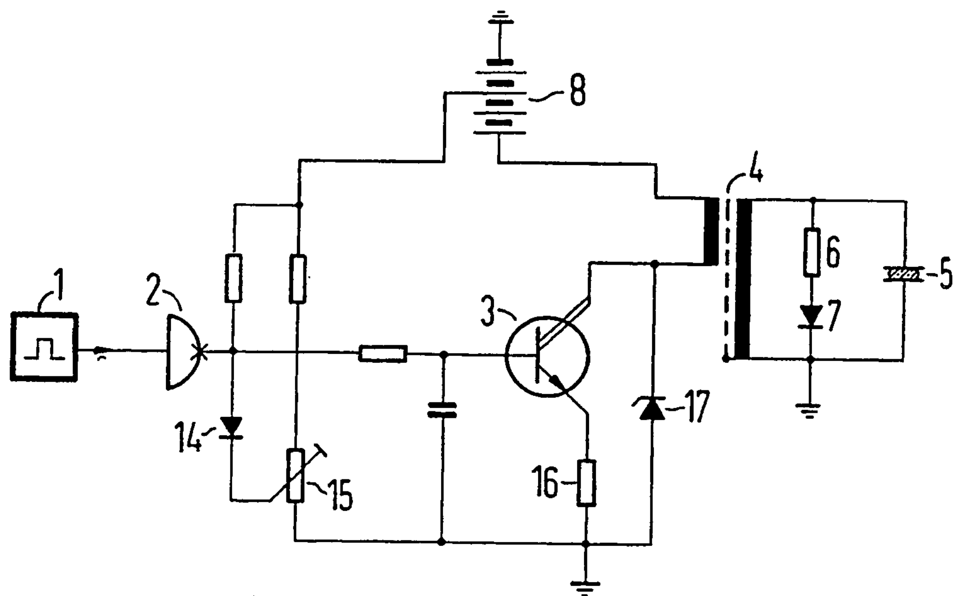


Fig. 2

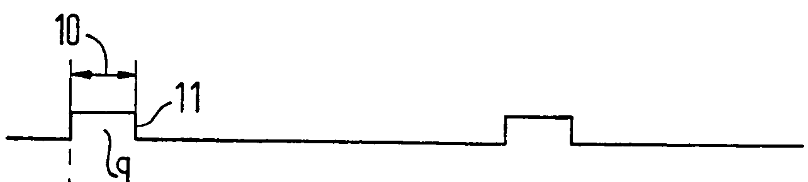
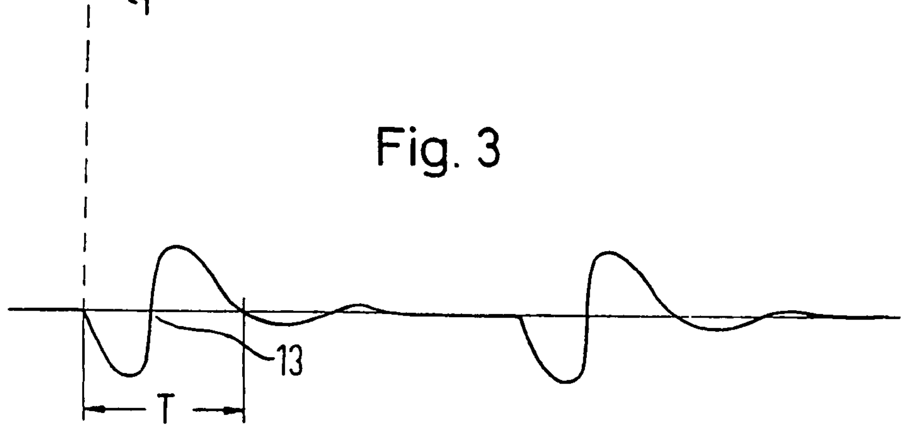


Fig. 3



1 510 091 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale.

SHEET 2

Fig. 4